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EUREKA 269 - FATIGUE TESTS ON BOLTED SPECIMENS
Overview of test results and qualitative analysis

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CONTENTS

SUMMARY

In this report the results of fatigue tests carried out by TNO and TWI on friction grip bolted joints made from aluminium 6061 alloy are interpreted. Attention is given to the following parameters:

- strip or beam specimen;
- bolt configuration;
- plate thickness;
- failure mode.

Qualitative conclusions are made and also a suggestion for a design curve is given.

1 INTRODUCTION

In the EUREKA EU 269 project the influence of the following testing parameters on the fatigue behaviour of friction grip bolted joints are studied:

- one aluminium alloy (6061-T6);
- one detail (overlap joint with cover plates on both sides);
- one surface treatment (lightly shot blasting);
- two thicknesses (6 and 12 mm plate thickness);
- two bolt configurations.

Both tests on strips and I-shaped beams are done.
Additional to the main test programme some tests are done by TWI on 3 mm thick specimens and specimens with another surface treatment (degreasing). Also these results are presented.

A description of the test programme, design of the specimens and test results are reported in references [1] and [2]. Chapter 2 gives an overview. A comparison of the test results is made in chapter 3. This comparison is based on qualitative considerations. The parameters of influence already mentioned are:

- the plate thickness effect;
- the influence of the bolt configuration;
- the difference between strip and beam specimens.

Other parameter considered are:

- the observed type of failure;
- the surface treatment.

Conclusions on basis of this analysis, are made in chapter 4. Also some attention is given to a design curve.

2 TEST PROGRAM AND RESULTS

For the test programme one detail is used: an overlap joint with cover plates on both sides. The fatigue tests are done for three plate thicknesses (3, 6 and 12 mm). Two bolt configurations, one with two bolts and one with four bolts in line with the applied axial load, are considered. Table 1 gives a summary of the complete test programme carried out by TNO and TWI. Both references [1] and [2] give more information.

All the fatigue tests are done for a constant amplitude load. The experimental data given in references [1] and [2] is summarized in tables 2 to 8. In the tables the following parameters which might be important for the evaluation of the results, are considered:

- Loading. The applied stress range and stress ratio is given.
- Experimental data. The total number of cycles until failure and the way the specimen failed is given. In general two failure modes are distinguished. For the first one the crack started at the location of the bolt hole and grew into the main plate. For the second one the crack initiated by the so called fretting process and grew into the main plate.

3 COMPARISON AND INTERPRETATION

3.1 Strip or beam

In figures 1 to 3 the results of the strips are compared with the results of the beams.
The following is observed:
- 6 mm + 2 bolts, no significant difference between strips and beams;
- 12 mm + 2 bolts, life time for beams are approximately a factor 5 lower than for strips, which is probably caused by the fact that the compressed area differs from each other;
- 12 mm + 4 bolts, same conclusion as for 12 mm + 2 bolts.

3.2 Bolt configuration

In figures 4 and 5 the results of the 2 bolt configurations are compared with the results of the 4 bolt configurations. Run outs are not taken into account.
No significant difference in life time can be observed.

3.3 Thickness

In figure 6 and 7 the results of the 3, 6 and 12 mm specimens with a 2 bolt configuration are compared with each other. Run outs are not taken into account.
The test results of the strips show no influence of the thickness, while the test results of the beams show a significant difference. The 12 mm beams give lower life times than the 6 mm beams.

3.4 Failure mode

In figures 8 to 10 the observed failure modes crack initiates at the hole and fretting, are compared with each other.
No significant difference is observed.

3.5 Surface

The number of test results with the surface treatment degreasing instead of shot blasting, is too limited to make any conclusion.

4 CONCLUSIONS

In chapter 3 a qualitative analysis of the test results is made. The results of this analysis indicate that it is very difficult to draw general conclusions. It is therefore advised to carry out a statistical analysis with the multiple linear regression method. The influencing parameters strip or beam specimen, bolt configuration, thickness and failure mode can be taken into account. It might also be fruitful to take the test results of the other international EUREKA 269 partner i.e. Alures into account.

The conclusion of phase I of the EUREKA project [3] that literature indicates that test results of 100 N/mm_2 at $2x10^6$ are normal, is in agreement with the test results.
The BS 8118 [3] classifies the friction grip bolt as type number 1.5 with a maximum permitted class of 29 N/mm^2 at $2 \cdot 10^6$ with a slope of 3. The classification of 29 N/mm_2 at $2x10^6$ is very low compared with the test results presented in this report and the figures indicate that a slope of 4 is more realistic.

REFERENCES

[1] Van Straalen, IJ.J., Soetens, F., 'Fatigue test results bolted specimens (TNO-tests) - Background report EUREKA project EU 269 'Design of Aluminium Structures under Fatigue Loading'', TNO-report 93-CON-R0970, August 1993.

[2] Maddox, S.J., 'Design of aluminium structures under fatigue loading - Final report', TWI-report 8132/8/93, October 1993.

[3] 'Structural use of aluminium - Part 1. Code of practice for design', British standard BS 8118 : Part 1 : 1991, British Standard Institute, 1991.

[4] Soetens, F., Dijkstra, O.D., Van Straalen, IJ.J., 'Inventory of fatigue behaviour of friction grip bolted connections in aluminium structures', TNO-report B-89-873, February 1989.

Table 1: Summary test programme

thickness	bolt configuration	specimen	laboratory
3 mm	2	strip	TWI
6 mm	2	strip	TNO
			TWI
		beam	TNO
12 mm	2	strip	TNO
			TWI
		beam	TNO
	4	strip	TNO
			TWI
		beam	TNO

Table 2: Results of 3 mm plate, two bolt configuration, strip specimen

specimen number	labo	$\Delta\sigma$ N/mm^2	R	N	failure mode
88132-22	TWI	135	0.1	575800	fretting
88132-24	TWI	126	0.1	501300	hole
88132-19	TWI	126	0.1	507700	hole
88132-25	TWI	108	0.1	632700	fretting
88132-26	TWI	90	0.1	> 14600000	none
88132-17	TWI	90	0.1	> 2627100	none
88132-32[1)]	TWI	50	0.1	> 57310000	none
88132-30[1)]	TWI	45	0.1	> 49450000	none
88132-31[1)]	TWI	45	0.1	> 49670000	none
88132-28[1)]	TWI	36	0.1	> 51220000	none

[1)] Surface degreased instead of shot-blasted

Table 3: Results of 6 mm plate, two bolt configuration, strip specimen

specimen number	labo	$\Delta\sigma$ N/mm^2	R	N	failure mode
BS206-02C	TWI	160	0.1	188700	?
BS206-06C	TWI	160	0.1	164300	?
BS206-09C	TNO	160	0.1	145800	hole
BS206-10C	TNO	160	0.1	132600	hole
BS206-03C	TWI	130	0.1	> 1962400	none
BS206-04C	TWI	130	0.1	> 2004300	none
BS206-11C	TNO	120	0.1	2596600	hole
BS206-12C	TNO	120	0.1	3547600	fretting
BS206-05C	TWI	100	0.1	> 2026400	none
BS206-01C	TWI	100	0.1	> 14600000	none
BS206-13C	TNO	90	0.1	> 12121200	none
BS206-14C	TNO	90	0.1	> 10000000	none
88132-40	TWI	126	0.1	847600	hole
88132-38	TWI	108	0.1	1156600	hole
88132-41	TWI	108	0.1	6116700	hole
88132-39	TWI	90	0.1	> 19528200	none
88132-42	TWI	90	0.1	> 2354200	none
88132-45[1)]	TWI	25	0.1	1052700	fretting
88132-47[1)]	TWI	80	0.1	1406100	fretting
88132-49[1)]	TWI	50	0.1	3251100	fretting
88132-46[1)]	TWI	40	0.1	> 34000000	fretting

[1)] Surface degreased instead of shot-blasted

Table 4: Results of 12 mm plate, two bolt configuration, strip specimen

specimen number	labo	$\Delta\sigma$ N/mm^2	R	N	failure mode
BS212-01C[1)]	TWI	160	0.1	256000	?
BS212-02C	TWI	160	0.1	146000	?
BS212-09C[1)]	TNO	160	0.1	> 183000	none
BS212-10C	TNO	160	0.1	> 178500	none
BS212-03C[1)]	TWI	130	0.1	879500	hole/?
BS212-04C	TWI	130	0.1	575300	hole
BS212-11C[1)]	TNO	120	0.1	460600	fretting
BS212-12C	TNO	120	0.1	> 463100	none
BS212-05C[1)]	TWI	100	0.1	885000	hole
BS212-06C	TWI	100	0.1	2519300	fretting?
BS212-13C[1)]	TNO	90	0.1	3930300	fretting
BS212-14C	TNO	90	0.1	2824700	fretting

[1)] Rotabolts used

Table 5: Results of 12 mm plate, four bolt configuration, strip specimen

specimen number	labo	$\Delta\sigma$ N/mm^2	R	N	failure mode
BS412-01C[1)]	TWI	160	0.1	188000	hole
BS412-04C	TWI	160	0.1	215000	hole
BS412-09C[1)]	TNO	160	0.1	157500	hole
BS412-10C	TNO	160	0.1	160000	hole
BS412-03C[1)]	TWI	130	0.1	684000	hole
BS412-06C	TWI	130	0.1	> 599000	none
BS412-11C[1)]	TNO	120	0.1	698400	fretting
BS412-12C	TNO	120	0.1	772500	fre/hole?
BS412-05C[1)]	TWI	100	0.1	1862400	?
BS412-02C	TWI	100	0.1	1704100	?
BS412-13C[1)]	TNO	90	0.1	983900	fretting
BS412-14C	TNO	90	0.1	3197100	fretting

[1)] Rotabolts used

Table 6: Results of 6 mm plate, two bolt configuration, beam specimen

specimen number	labo	$\Delta\sigma$ N/mm^2	R	N	failure mode
BB206-01C	TNO	160	0.1	204400	fretting
BB206-04C	TNO	120	0.1	> 1247700	none
BB206-03C	TNO	90	0.1	> 3718900	none
BB206-05C	TNO	90	0.1	6731700	fretting

Table 7: Results of 12 mm plate, two bolt configuration, beam specimen

specimen number	labo	$\Delta\sigma$ N/mm^2	R	N	failure mode
BB212-02C	TNO	180	0.1	> 33280	none
BB212-03C	TNO	180	0.1	39870	fretting
BB212-01C	TNO	120	0.1	297100	fretting
BB212-04C	TNO	90	0.1	867470	fretting

Table 8: Results of 12 mm plate, four bolt configuration, beam specimen

specimen number	labo	$\Delta\sigma$ N/mm^2	R	N	failure mode
BB412-02C	TNO	180	0.1	33360	fretting
BB412-01C	TNO	120	0.1	152010	fretting
BB412-03C	TNO	90	0.1	> 840600	none
BB412-04C	TNO	90	0.1	675780	fretting

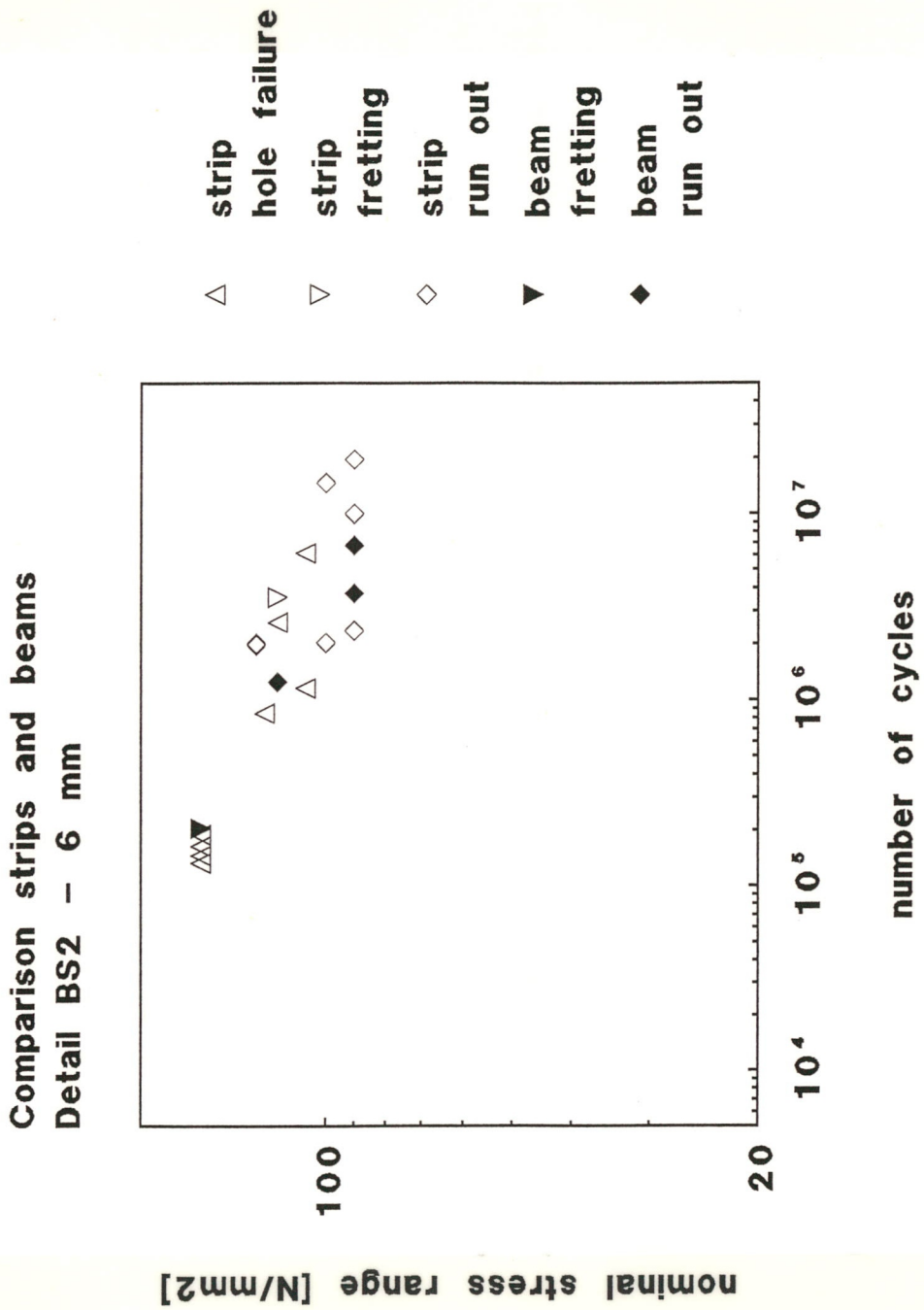

Figure 1 - Comparison strips and beams 2 bolt configuration, 6 mm

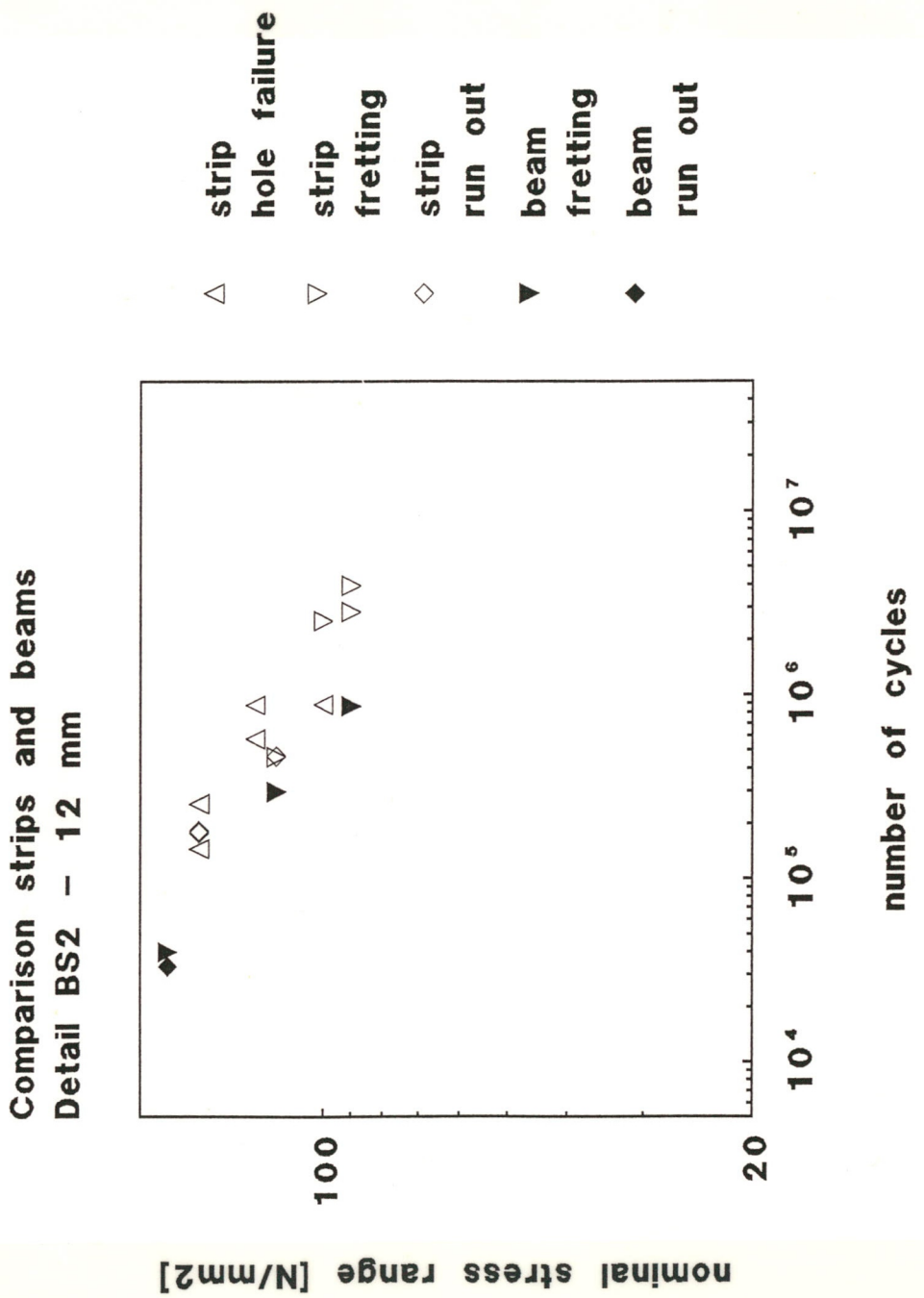

Figure 2 - Comparison strips and beams 2 bolt configuration, 12 mm

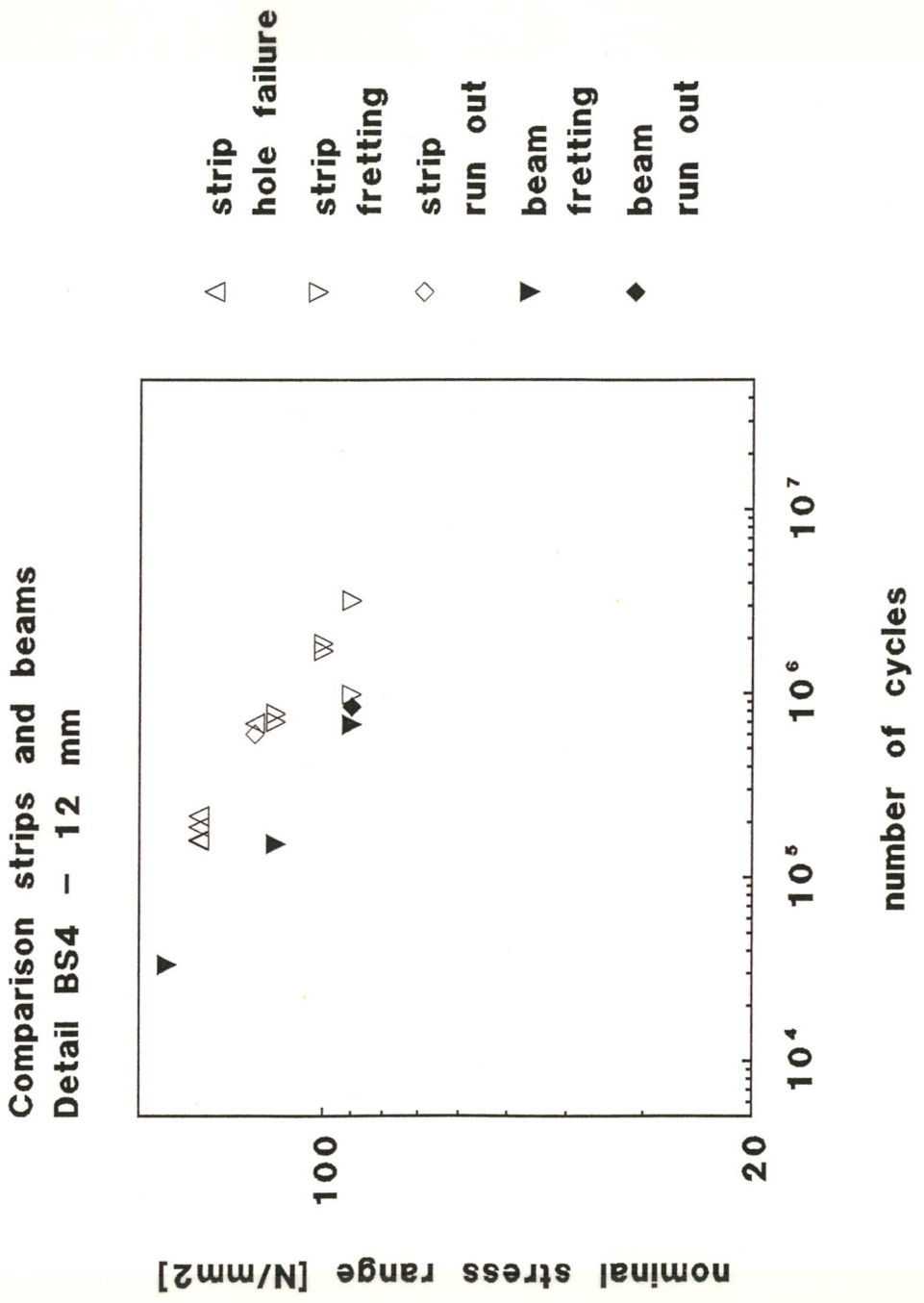

Figure 3 - Comparison strips and beams 4 bolt configuration, 12 mm

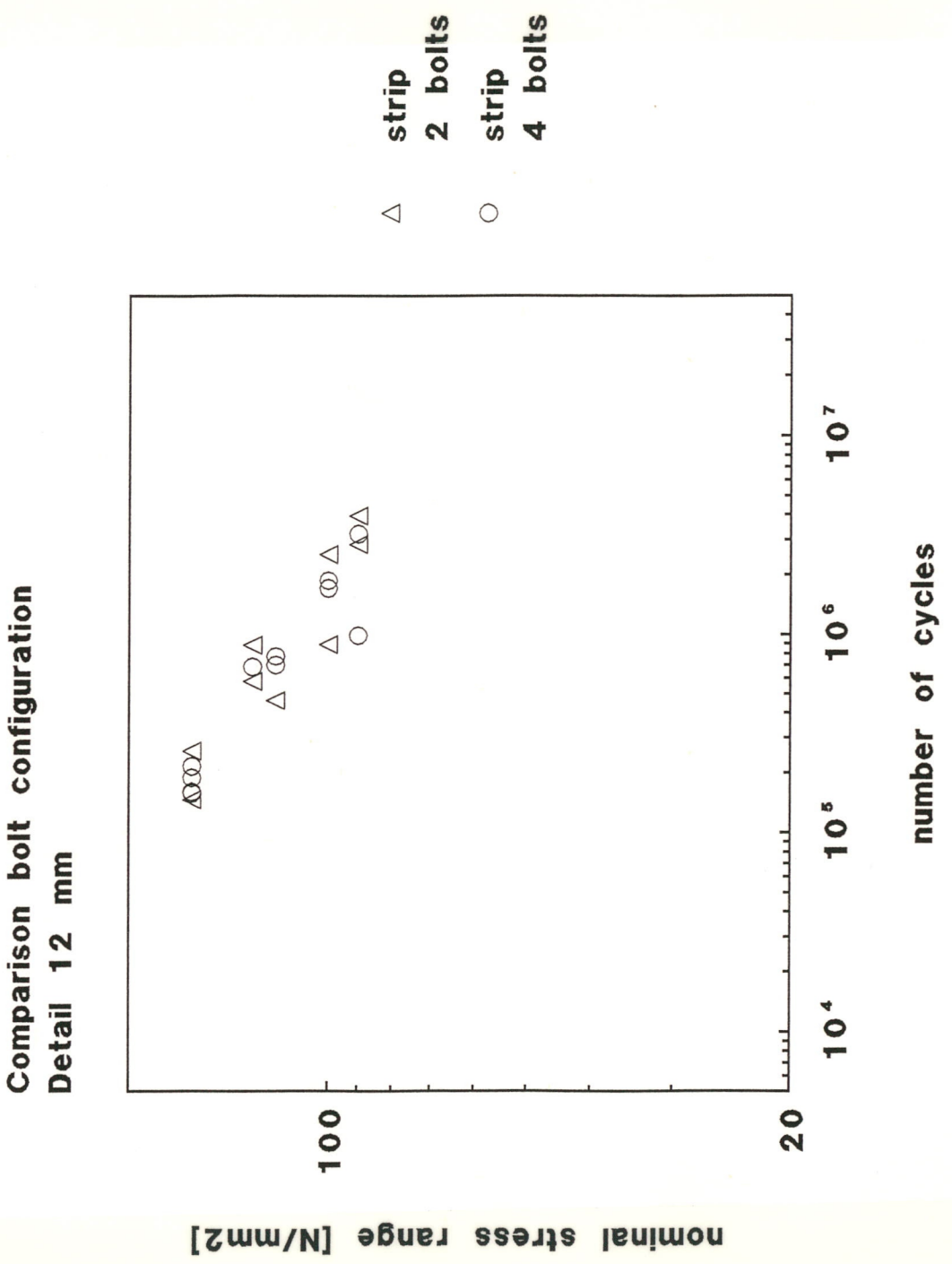

Figure 4 - Comparison bolt configurations for strips

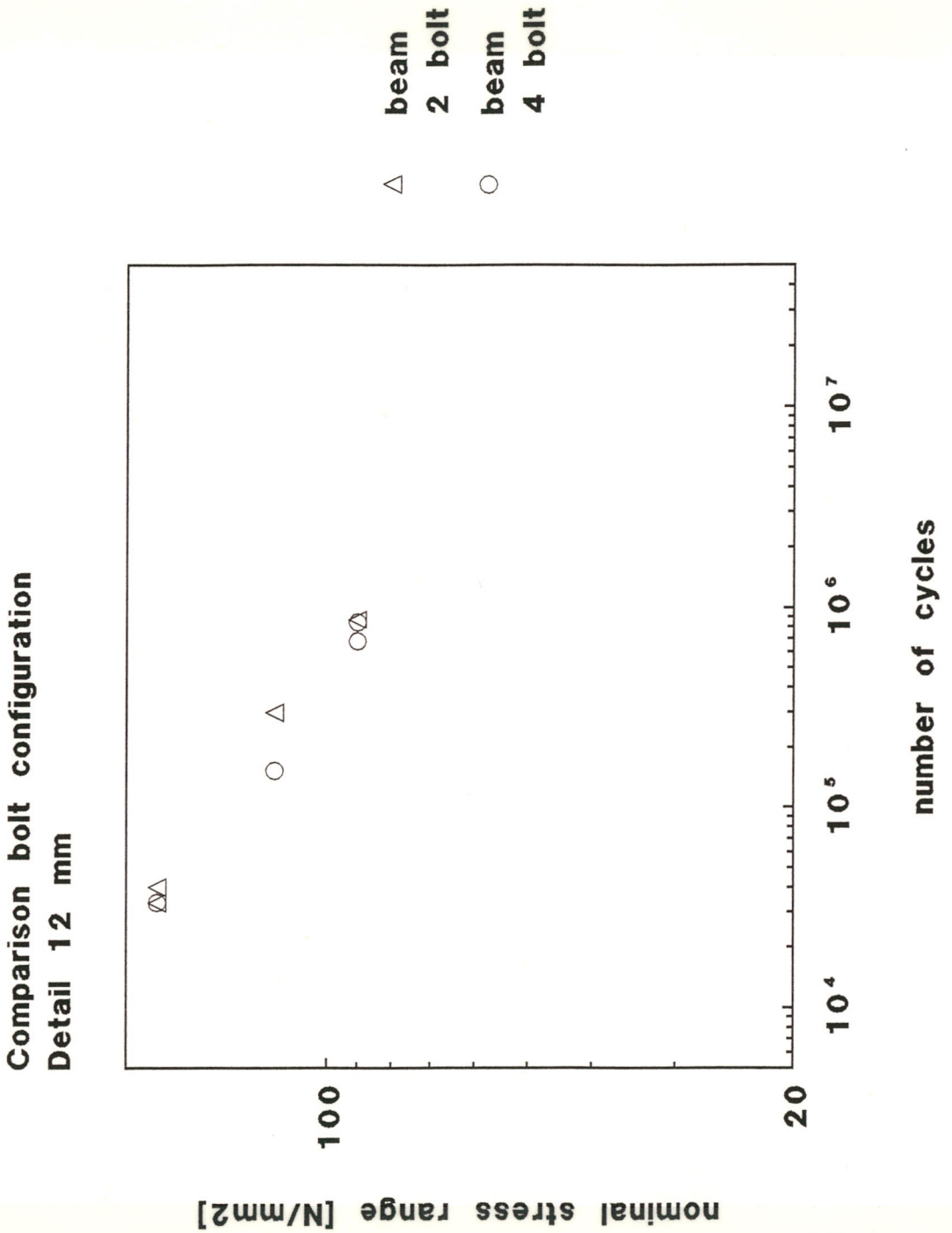

Figure 5 - Comparison bolt configurations for beams

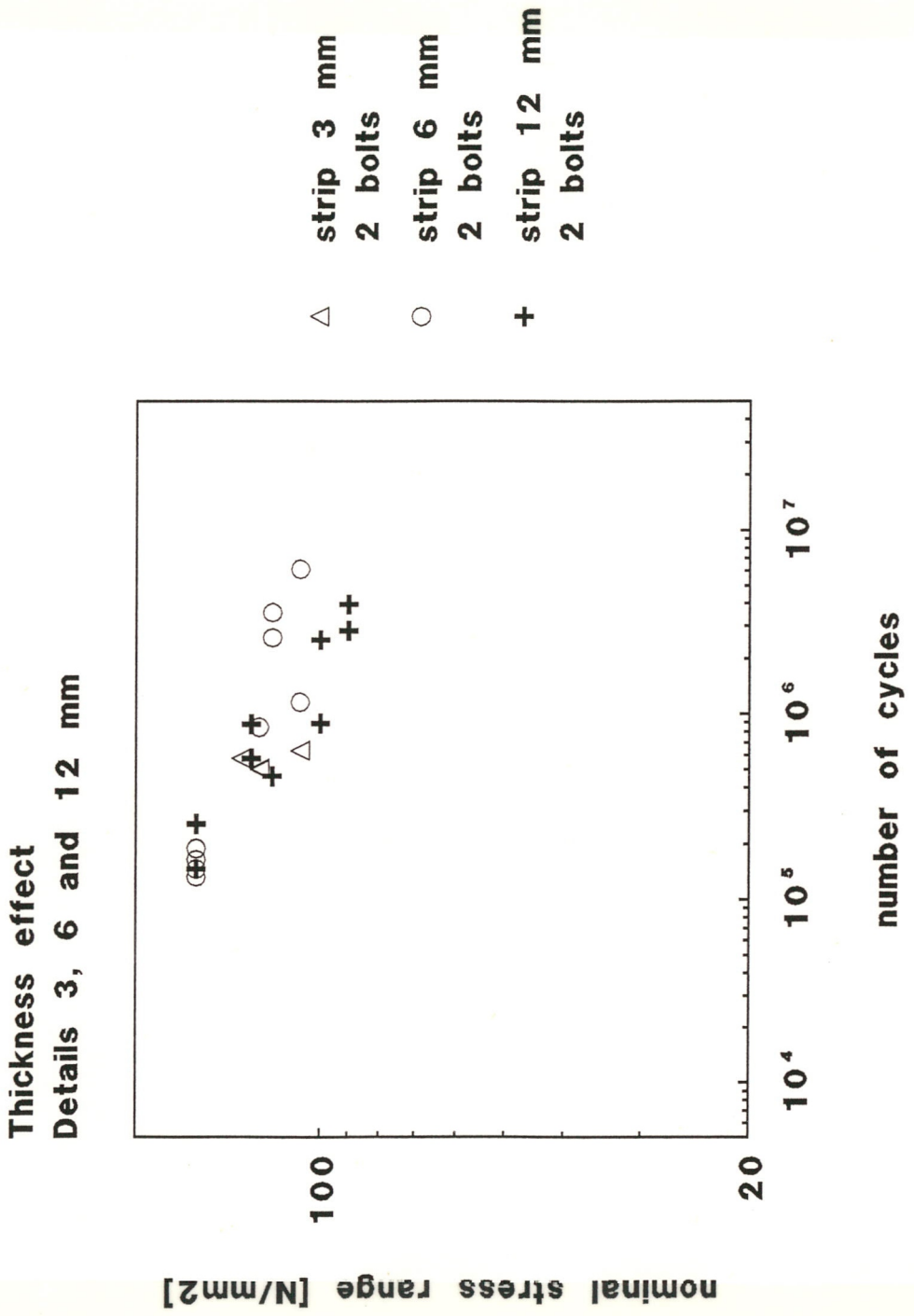

Figure 6 - Thickness effect for strips

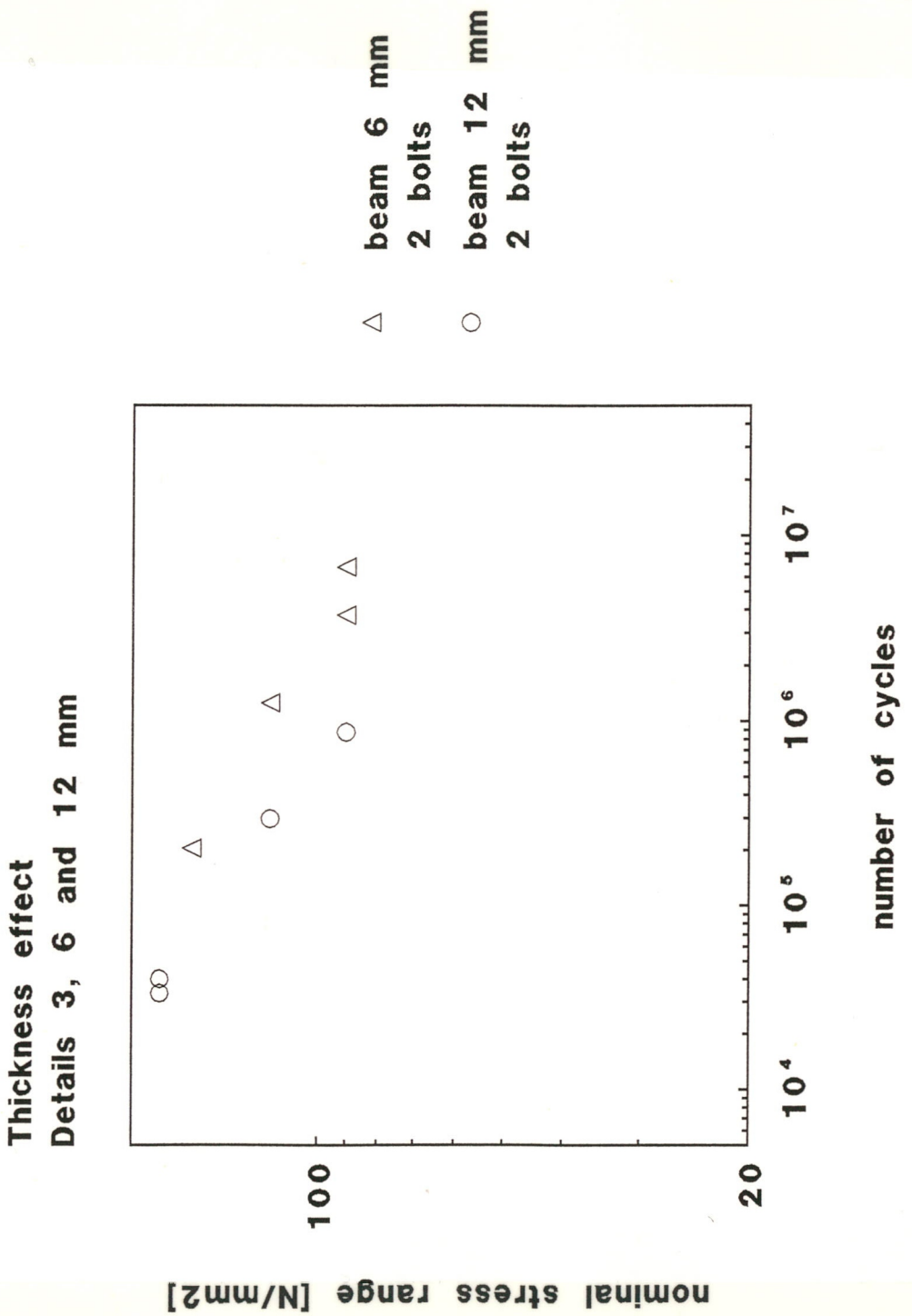

Figure 7 - Thickness effect for beams

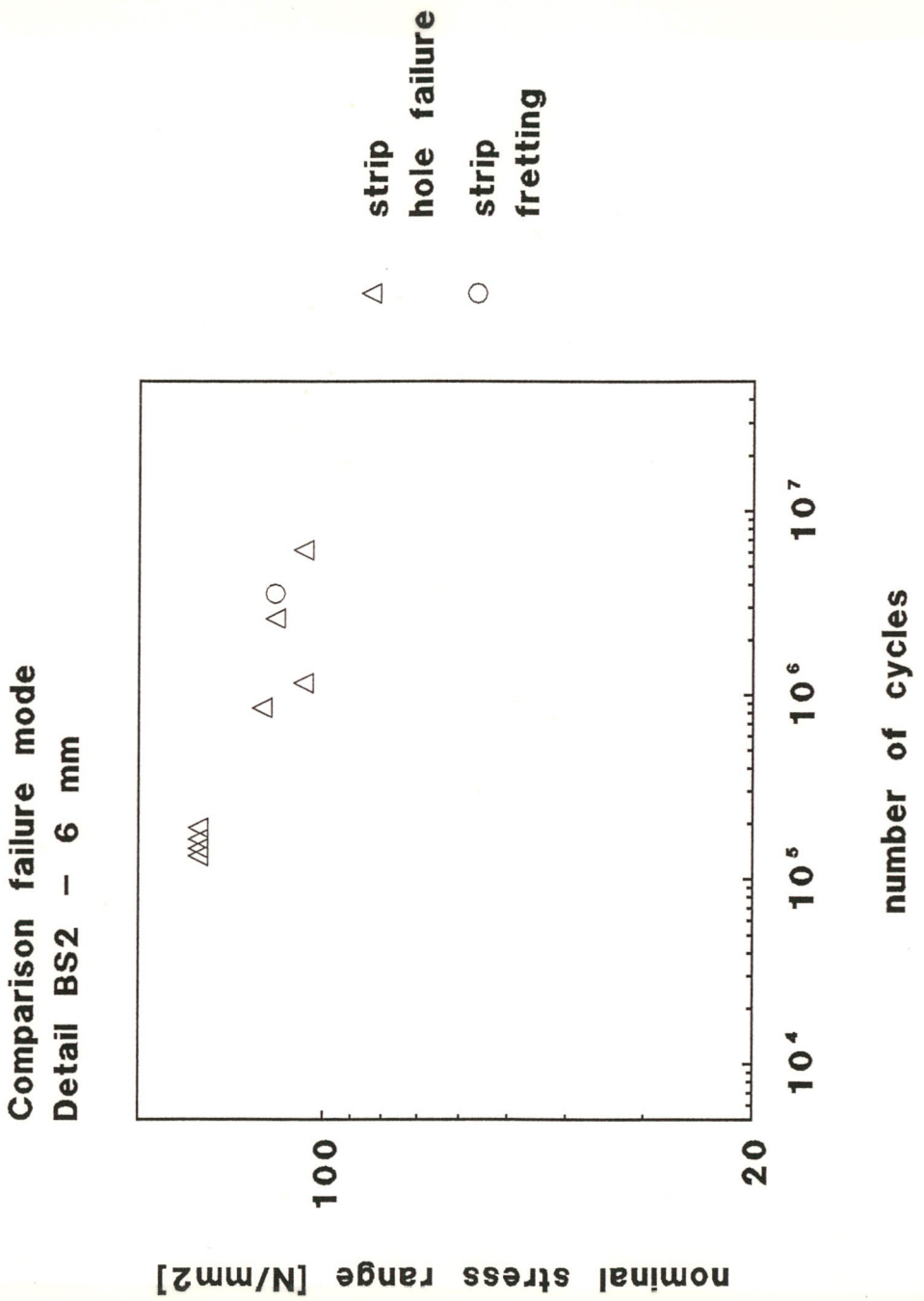

Figure 8 - Comparison failure mode 2 bolt configuration, 6 mm

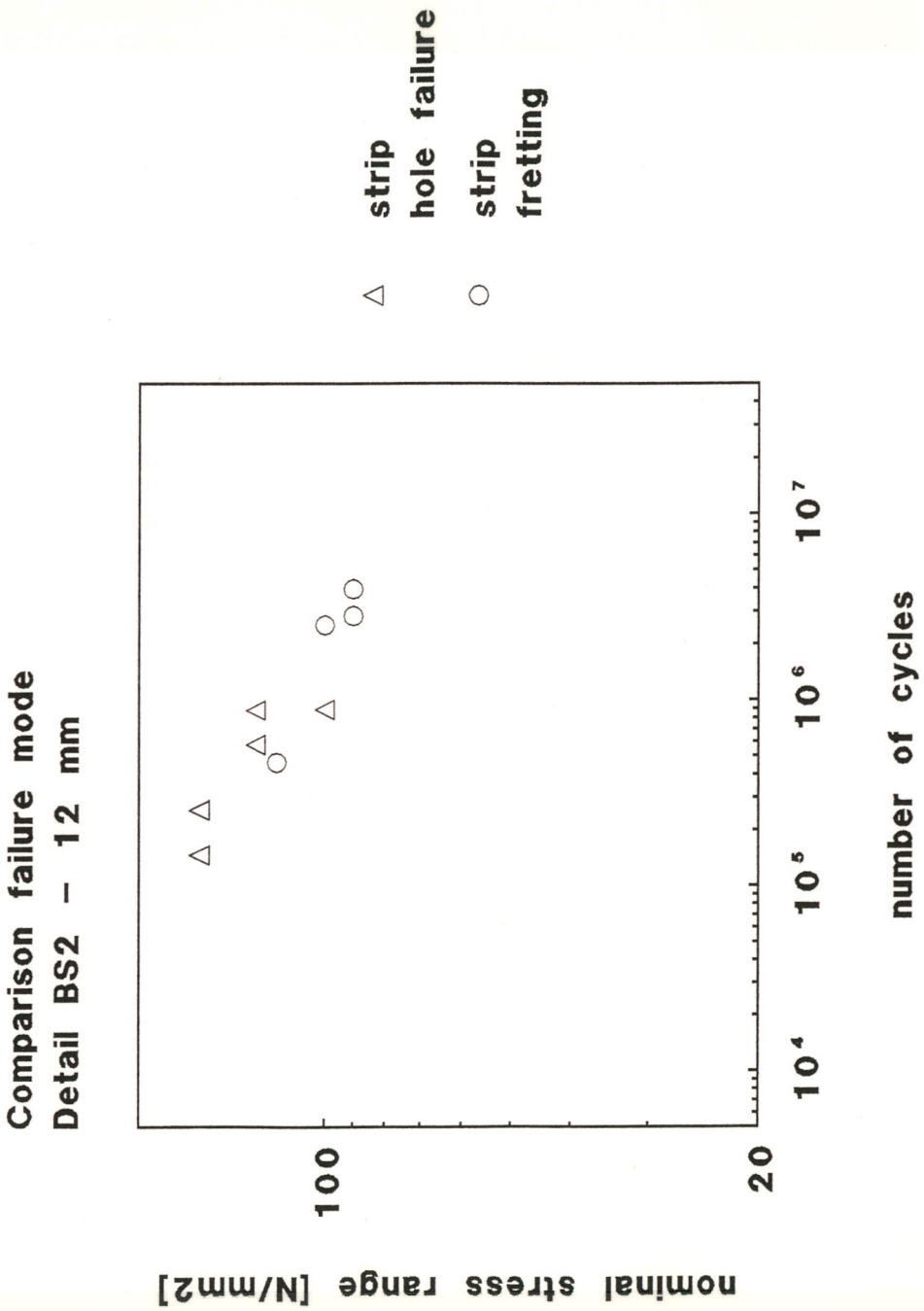

Figure 9 - Comparison failure mode 2 bolt configuration, 12 mm

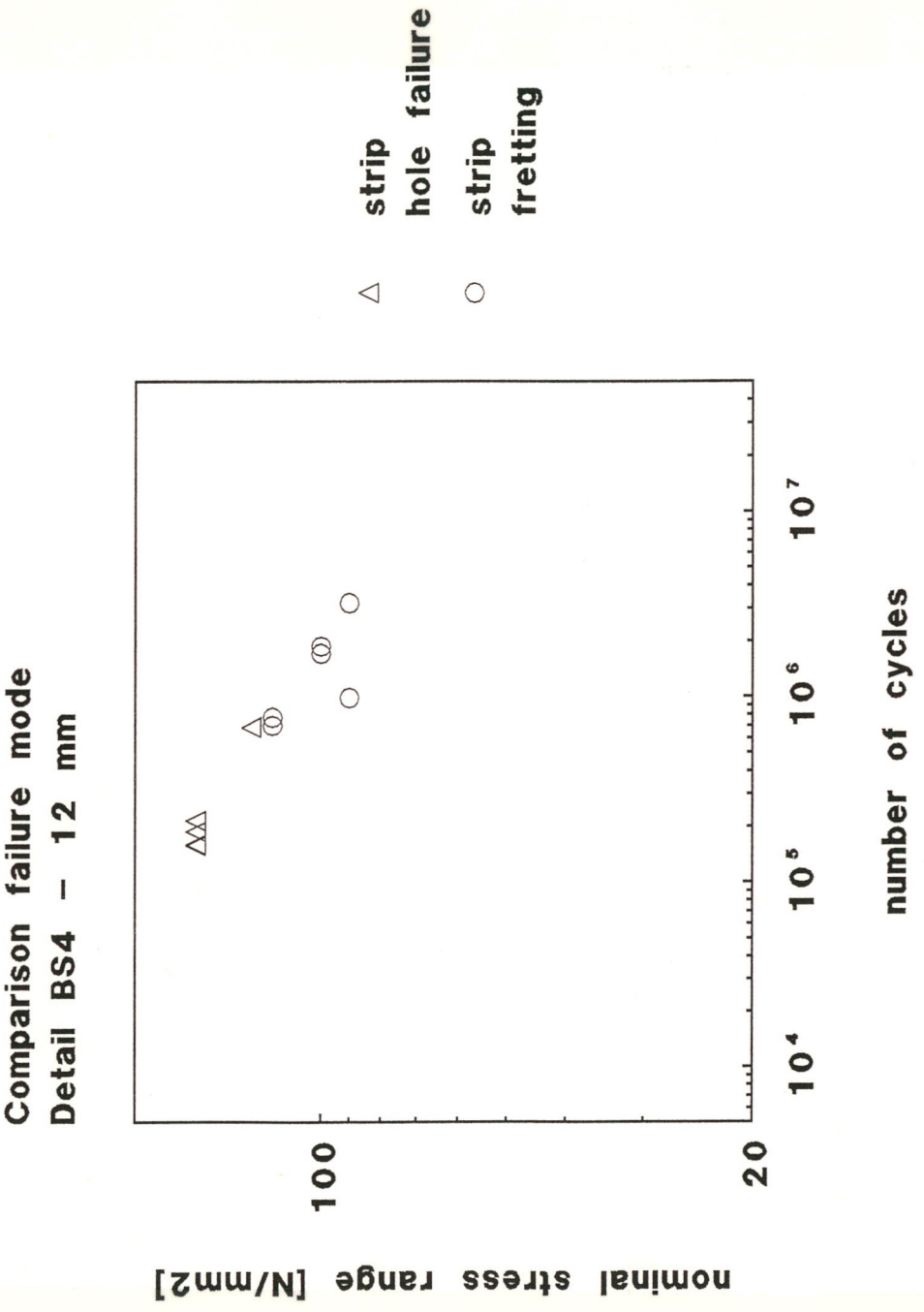

Figure 10 - Comparison failure mode 4 bolt configuration, 12 mm